

Nutritionally altering weight gain patterns of pregnant heifers and young cows changes the time that feed resources are offered without any differences in production¹

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ABSTRACT: We hypothesized that feed resources could be deferred to a later time in the production cycle without a decrease in fertility or weight of calf produced in heifers and young cows. One-hundred and thirty-one MARC III (four breed composite: ¼ Hereford, ¼ Angus, ¼ Red Poll, and ¼ Pinzgauer) heifers were divided into three treatments: M-M-M-M (n = 46), L-H-M-M (n = 41), and L-L-L-H (n = 44). The experiment consisted of four feeding periods. Period 1 was 94 to 186 d of gestation, and heifers were fed a moderate (M) or low (L) level of feed. Period 2 was 187 d of gestation to parturition, and heifers were fed moderate, high (H), or low levels of feed. Period 3 was from parturition through 27 d of lactation, and heifers were fed moderate or low levels of feed. Period 4 was from 28 d to approximately 63 d of lactation, and heifers were fed moderate or high levels of feed. Females remained within treatments

through their first parity (heifers) and second parity (cows). Feed intake of L-H-M-M and M-M-M-M treatments did not differ from each other either as heifers ($P = 0.23$) or as second-parity cows ($P > 0.59$). The L-L-L-H heifers ate less feed than L-H-M-M and M-M-M-M heifers ($P < 0.001$), and second-parity L-L-L-H cows ate less feed than second-parity L-H-M-M and M-M-M-M cows ($P < 0.002$). In the first parity, treatments did not differ in the percentage of calves weaned ($P = 0.11$), weight of calf weaned ($P = 0.50$), or percentage of cows diagnosed pregnant ($P = 0.29$) with a second calf. In the second parity, treatments did not differ in the percentage of calves weaned ($P = 0.77$), weight of calf weaned ($P = 0.63$), or percentage of cows expressing a corpus luteum at the start of breeding for their third calf ($P = 0.21$). Our findings suggest that timing nutrient availability to heifers and primiparous cows can be used to change the time that feed resources are used.

Key Words: Cows, Lactation, Nutrition, Pregnancy

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Introduction

Nutrient requirements of the cow fluctuate throughout the year. Nutrient availability fluctuates throughout the year in grazed forage-based production systems. Seasonal variation in markets and other external factors frequently dictate that matching nutrient requirements to nutrient availability is not always the best economic model. Freetly and Nienaber (1998) found that the efficiency of energy and N retention of mature nonpregnant, nonlactating cows increased in cows that were previously feed restricted. Based on these find-

ings, they proposed that fluctuating BW through nutrition could be used as a strategy to shift the time nutrients are provided to cows; however, cow fertility can be decreased if nutritional insult occurs at an inappropriate time in the production cycle (Wiltbank et al., 1962; Bellows and Short, 1978; DeRouen et al., 1994). The studies of Selk et al. (1988) and Whittier et al. (1988) suggest that cows that return to an acceptable weight at breeding can fluctuate in weight without decreasing fertility. Freetly et al. (2000) found that neither fertility nor weight of calf produced differed between mature cows managed for limited BW gain during mid-pregnancy followed by rapid BW gain during late pregnancy and cows managed for moderate weight gain throughout pregnancy. Heifers are still growing during their first pregnancy and lactation, which results in an increased need for nutrients beyond that needed for maintenance, lactation, and pregnancy. This increase in required nutrients suggests that heifers and young cows may be more sensitive to fluctuations in feed availability than mature cows. We hypothesized that feed re-

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sources could be deferred to a later time in the production cycle without a decrease in fertility or weight of calf produced in heifers and young cows managed for minimal weight gain during pregnancy followed by rapid weight gain either during late pregnancy or early lactation.

Materials and Methods

One hundred and thirty-one MARC III (four breed composite: ¼ Hereford, ¼ Angus, ¼ Red Poll, and ¼ Pinzgauer) heifers were used over a 2-yr period. Heifers were bred by AI to a single MARC III bull. Heifers were 437 ± 1 d of age at breeding and were bred over a 21-d period beginning on October 30. Pregnancy was confirmed with ultrasound 35 d after breeding. Following breeding, heifers were stratified by breeding date and randomly assigned to one of three treatments across levels of stratification. Heifers were divided into three treatments: **M-M-M-M**, **L-H-M-M**, and **L-L-L-H**. The experiment consisted of four feeding periods. Period 1 was 94 to 186 d of gestation, and heifers were fed a moderate (M) or low (L) level of feed. Period 2 was 187 d of gestation to parturition, and heifers were fed moderate, high (H), or L levels of feed. Period 3 was from parturition through 27 d of lactation, and heifers were fed M or L levels of feed. Period 4 was from 28 d to approximately 63 d of lactation, and heifers were fed M or H levels of feed. In the first year, there were 25 heifers in M-M-M-M, 20 heifers in L-H-M-M, and 23 heifers in L-L-L-H; in the second year, there were 21 heifers in each of the treatments. Care of the heifers complied with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999). Data were collected during two consecutive pregnancies. Heifers remained within treatments during the study, but actual feed intakes differed between their pregnancy as a heifer and their pregnancy as a cow. Cattle received the same total mixed diet that consisted (DM basis) of 67.3% corn silage, 27% alfalfa hay, 5.5% corn, and 0.2% sodium chloride) both as heifers and cows. The diet had a calculated ME value of 2.39 Mcal/kg of DM. As heifers, feed was provided to allow for maternal BW gain (growth) until mating for their second calf, whereas no feed was allotted for growth as cows.

Heifers (First Parity)

Heifers were penned four or fewer to a pen and fed individually by use of Calan electronic headgates (American Calan, Inc., Northwood, NH). Feed offered was adjusted throughout the study to practice three different management schemes. The M-M-M-M heifers were managed to gain maternal BW and maintain a moderate BCS throughout the study. The L-H-M-M heifers were fed to allow fetal growth in the second trimester but not to allow maternal BW gain. During the third trimester, L-H-M-M heifers were fed to allow

Table 1. Allotments of metabolizable energy for gain of pregnant and lactating heifers

	Mcal of ME/d ^a		
	M-M-M-M	L-H-M-M	L-L-L-H
Gestation			
94 to 186 d	3.5	0	0
187 d to parturition	3.5	7.0	0
Lactation			
Parturition to 28 d	3.5	3.5	0
28 to 29 d	3.5	3.5	5.35
30 to 31 d	3.5	3.5	10.7
32 to 33 d	3.5	3.5	16.05
34 d to breeding ^b	3.5	3.5	21.4

^aM-M-M-M heifers were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M heifers were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H heifers were fed to have low BW gains from 94 d of gestation through 27 d of lactation and rapid BW gain from 28 d of lactation until breeding.

^bApproximately 66 d.

rapid maternal BW gain such that their BW at calving would not differ from the M-M-M-M heifers. The L-L-L-H heifers were managed to not allow maternal BW gain from the start of the second trimester until 28 d postpartum. Starting at 28 d postpartum, L-L-L-H heifers were fed to allow rapid BW gain such that BW at breeding (63 d postpartum) would not differ from the M-M-M-M heifers.

Heifers were weighed every 2 wk, and ME intake (ME_i) was calculated based on BW and days pregnant or days lactating. Metabolizable energy intake was calculated by the following equation:

$$ME_i = ME_m + ME_y + ME_l + ME_g$$

Treatments received equal allocations for ME for maintenance (ME_m), conceptus (ME_y), and lactation (ME_l), but differed in their allocations for gain (ME_g ; Table 1). Metabolizable energy was calculated from the following equations and Table 1:

$$ME_m = 0.135(\text{Heifer BW}_{\text{kg}})^{0.75}$$

where

$$\begin{aligned} \text{Heifer BW} &= (\text{BW} - \text{gravid uterus weight}); \\ \text{gravid uterus weight} &= 40/38.5(0.7439e^{(0.0199694 - 0.0000143t)t}); \\ t &= \text{days pregnant}; \\ ME_y &= (40(0.4504 - 0.000766t)e^{(0.03233 - 0.0000275t)t})/1,000; \\ t &= \text{days pregnant}; \\ ME_l &= (0.000001017t^3 - 0.000527192t^2 + 0.059944951t + 5.091)/1.0844; \text{ and} \\ t &= \text{days lactating}. \end{aligned}$$

Daily feed offered and weekly feed refusals were measured. Additional feed refusals were measured at 94 d

gestation, 187 d gestation, parturition, 28 d lactation, and at breeding.

During gestation, BW were measured 94 d after mating and then every 2 wk until parturition. An additional BW measurement was made at 187 d of gestation. Heifer and calf BW was measured at parturition and BW was measured weekly for both cows and calves for the next 4wk. Following the initial 4 wk after calving, BW was measured every 2 wk until breeding. Heifer BCS (1 = thin to 9 = fat) was determined at 187 d of gestation, parturition, and breeding.

Between 63 to 69 d after calving, treatments were commingled, and heifers and their calves were moved to a breeding pasture. Heifers that did not have a nursing calf at breeding were removed from the study. Heifers were multisire mated (1 bull:25 cows) for 64 d. During breeding, heifers received 12.7 kg of DM/d of a diet that contained 70% haylage and 30% corn silage (DM basis).

Calves were weaned at 152 ± 1 d of age and calves were placed in a dry lot. Treatments were commingled and penned by sex. Calves had ad libitum access to feed. Calves were weighed 10, 24, 31, and 39 wk following weaning.

At weaning, heifers were returned to individual feeding. Heifers were palpated 97 ± 2 d after being removed from breeding. Heifers that were not pregnant were removed from the study and pregnant cows continued into the second year of the study as bred cows.

Cows (Second Parity)

Feed offered was adjusted throughout the study to practice three different management schemes. The M-M-M-M cows were managed to maintain maternal BW at a moderate BCS through out the study. The L-H-M-M cows were fed to lose maternal BW during the second trimester such that they would be one BCS lower than the M-M-M-M cows at the start of the third trimester. During the third trimester, L-H-M-M cows were fed to allow for rapid maternal BW gain such that BW at calving would not differ from the M-M-M-M cows. The L-L-L-H cows were managed like the L-H-M-M cows during the second trimester and then were fed to maintain reduced maternal BW until 28 d postpartum. Starting at 28 d postpartum, L-L-L-H cows were fed to allow rapid BW gain, such that BW at breeding (63 d postpartum) would not differ from the M-M-M-M cows.

Cow BW at a BCS of 5.5 was calculated at weaning by adding 45 kg for every BCS less than 5.5 or subtracting 45 kg for every BCS score over 5.5 (NRC, 1996). Allocations for ME for maintenance during the second year were based on the calculated BW at BCS 5.5. Metabolizable energy intake was calculated by the following equation:

$$ME_i = ME_m + ME_y + ME_l$$

Treatments received equal allocations for ME for conceptus (ME_y) and lactation (ME_l), but differed in their

Table 2. Allocation of ME for maintenance (ME_m) for pregnant and lactating cows

	ME_m , kcal of ME/kg BW ^{0.75} ^a		
	M-M-M-M	L-H-M-M	L-L-L-H
Gestation			
112 to 201	135	100	100
202 to 205	135	114	100
206 to 208	135	128	100
209 to 211	135	142	100
212 to 214	135	156	100
215 to parturition	135	170	100
Lactation			
Parturition to 27 d	135	135	100
28 to 30	135	135	148.6
31 to 33	135	135	197.2
34 to 36	135	135	245.8
37 to 39	135	135	294.4
40 to breeding ^b	135	135	343

^aM-M-M-M cows were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M cows were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H cows were fed to have low BW gains from 94 d of gestation through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^bApproximately 64 d.

allocations for maintenance (ME_m ; Table 2). Metabolizable energy was calculated from the following equations and Table 2:

$$ME_y = (44.5 (0.4504 - 0.000766t)e^{(0.03233-0.0000275t)t})/1,000$$

where t = days mated + 18 d; and

$$ME_l = (0.00000137t^3 - 0.00071242t^2 + 0.081007t + 6.880)1.0844$$

where t = days lactating

Daily feed offered and weekly feed refusals were measured. Additional feed refusals were measured at 112 and 203 d after the start of breeding, parturition, 28, and approximately 63 d of lactation.

During gestation, BW were measured at 112 d after the start of breeding and then every 2 wk. Additional BW measurements were made 203 d after the start of breeding. Cow and calf BW was measured at parturition and BW was measured weekly for both cow and calf for the next 4 wk. Following the initial 4 wk after calving, BW was measured every 2 wk until calves were between 9 and 10 wk of age. Cow body condition score (1 = thin, 9 = fat) was determined at 203 d after breeding started, parturition, and at approximately d 63 of lactation. At approximately d 56 and 63 of lactation, ovaries were rectally palpated to determine the presence of a corpus luteum. Following the second palpation, treatments were commingled, and cows and their calves were moved to pasture. While on pasture, cows received 14 kg of DM/d of a diet that contained 70% alfalfa haylage and 30% corn silage (DM basis).

Calves were weaned at 186 ± 2 d of age and calves were placed in a drylot. Treatments were commingled

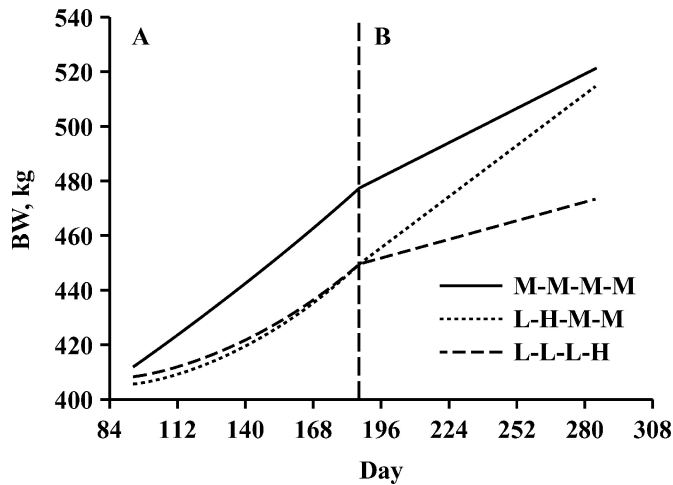


Figure 1. A) Body weight from 94 through 186 d of gestation of heifers fed moderately [—, M-M-M-M; $f(t) = 0.0010(\pm 0.0018)t^2 + 0.4107(\pm 0.5026)t + 364(\pm 34)$] or low [... , L-H-M-M; $f(t) = 0.0038(\pm 0.0024)t^2 - 0.5849(\pm 0.6664)t + 428(\pm 45)$] and ---, L-L-L-H; $f(t) = 0.0033(\pm 0.0022)t^2 - 0.4994(\pm 0.6087)t + 426(\pm 41)$]. B) Body weight from 187 d of gestation to parturition of heifers fed moderately [—, M-M-M-M; $f(t) = 0.4558(\pm 0.0523)t + 392(\pm 12)$], high [... , L-H-M-M; $f(t) = 0.6660(\pm 0.0668)t + 326(\pm 15)$], or low [---, L-L-L-H; $f(t) = 0.2479(\pm 0.0582)t + 403(\pm 14)$].

and penned by sex. Calves had ad libitum access to feed. Calves were weighed 10, 24, 31, and 39 wk following weaning.

Data Analyses

Heifer/cow feed intake, BW, BCS, and calf weight weaned per cow were analyzed using a factorial model. The model consisted of treatment, year, and treatment \times year and analyses were conducted with the GLM procedure in SAS (v. 6.1, SAS Inst., Inc., Cary, NC). Least squares means \pm SE are reported in the text and tables. Cow retention, weaning percent, and percentage of cows expressing a corpus luteum were analyzed with the

same model using the GENMOD procedure of SAS, with a binomial distribution specification. Means \pm SE are reported for cow retention, weaning percent, and percentage of cows expressing a corpus luteum in the text and tables. Calf BW and dry lot gain were analyzed using a factorial model. The model consisted of treatment, year, sex, treatment \times sex, treatment \times year, and sex \times year, and analyses were conducted with the GLM procedure in SAS. Least squares means \pm SE are reported in the text and tables. Calf BW gain in the drylot was the slope of BW on time from weaning through the feeding period. Body weight at 365 d of age was calculated using the (drylot ADG) \times (365 d – age at weaning) + weaning BW. Means were tested using least squares pairwise differences, with $P < 0.05$ considered significant.

Results

Heifers (First Parity)

Heifer Body Weight. From 94 through 186 d of gestation, BW increased quadratically at an increasing rate for all treatments, and treatments differed in both the quadratic (treatment \times time²; $P = 0.002$) and linear (treatment \times time; $P < 0.001$) terms (Figure 1). Rate of gain as a function of days increased linearly for M-M-M-M ($f(t) = 0.00207t + 0.411$), L-H-M-M ($f(t) = 0.00752t - 0.585$), and L-L-L-H ($f(t) = 0.00335t - 0.499$) heifers. Differences in gain were reflected in BW at 187 d of gestation. The M-M-M-M heifers weighed more at 187 d of gestation than the L-H-M-M and L-L-L-H ($P < 0.05$; Table 3). Heifer BCS differed between treatments at 187 d of gestation ($P < 0.05$) and treatments ranked from fattest to thinnest M-M-M-M, L-L-L-H, and L-H-M-M (Table 4).

From 187 d of gestation until parturition, BW increased linearly, and increases in BW differed among treatments (treatment \times time; $P < 0.001$). Rate of gain was greatest for the L-H-M-M heifers (0.67 ± 0.07 kg/d) followed by the M-M-M-M heifers (0.46 ± 0.05 kg/d), and least for the L-L-L-H heifers (0.25 ± 0.06 kg/d). At

Table 3. Body weights (kg) of first-calf heifers (values are least squares means \pm SE)

Treatment ^a	After mating					Lactation				
	n	94 d	n	187 d	n	Parturition	n	28 d	n	63 d
M-M-M-M	44	413 \pm 5	44	477 \pm 5 ^b	44	472 \pm 5 ^b	40	470 \pm 6 ^b	40	464 \pm 6
L-H-M-M	40	409 \pm 5	40	448 \pm 5 ^c	40	466 \pm 5 ^b	40	463 \pm 6 ^b	40	456 \pm 6
L-L-L-H	43	412 \pm 5	43	447 \pm 5 ^c	43	435 \pm 5 ^c	42	431 \pm 5 ^c	42	464 \pm 6
Pooled		412 \pm 3								461 \pm 3
Treatment (T)		0.78		<0.001		<0.01		<0.001		0.52
Year (Y)		<0.001		<0.001		0.39		0.23		0.71
T \times Y		0.49		0.42		0.68		0.73		0.36

^aM-M-M-M heifers were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M heifers were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H heifers were fed to have low BW gains from 94 d of gestation through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c}Within a column means without a common superscript letter differ, $P < 0.05$.

Table 4. Body condition score of first-calf heifers (values are least squares means \pm SE)^a

Treatment ^b	n	187 d	n	Parturition	n	Breeding
M-M-M-M	44	6.3 \pm 0.1 ^b	43	5.6 \pm 0.1 ^b	40	5.6 \pm 0.1
L-H-M-M	40	5.8 \pm 0.1 ^c	40	5.6 \pm 0.1 ^b	40	5.3 \pm 0.1
L-L-L-H	43	6.0 \pm 0.1 ^d	43	5.1 \pm 0.1 ^c	42	5.6 \pm 0.1
Pooled						5.5 \pm 0.1
Treatment (T)		<0.001		<0.001		0.10
Year (Y)		<0.001		<0.001		<0.001
T \times Y		0.25		0.34		0.62

^aM-M-M-M heifers were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M heifers were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H heifers were fed to have low BW gains from 94 d of gestation through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c,d}Within a column means without a common superscript letter differ, $P < 0.05$.

parturition, BW ($P = 0.45$; Table 3) and BCS ($P = 0.63$; Table 4) did not differ between M-M-M-M and L-H-M-M heifers ($P > 0.05$), but both treatments were greater than L-L-L-H heifers ($P < 0.001$).

Within the first 28 d after parturition, BW decreased in all treatments and then increased in a quadratic (time²; $P < 0.001$) manner (Figure 2). Treatments did not differ in either the quadratic (treatment \times time²; $P = 0.89$) or linear terms (treatment \times time; $P = 0.70$). The average nadir across treatments was 14.5 ± 2.1 d. Twenty-eight days after parturition, M-M-M-M and L-H-M-M heifers did not differ in BW ($P = 0.34$), but both were heavier than L-L-L-H heifers (Table 3; $P < 0.001$).

From 28 d of lactation until breeding (66.1 ± 0.2 d of lactation), BW changed quadratically over time and the change differed among treatments (treatment \times time²; $P < 0.001$). There was a general trend for a decrease in BW in the M-M-M-M and L-H-M-M heifers (Figure 2), but BW increased at a decreasing rate for the L-L-L-H heifers (Figure 2). At breeding, heifers did not differ in BW ($P = 0.52$; Table 3), nor did they differ in BCS ($P > 0.10$; Table 4).

Calf Body Weights. Birth weight of bulls was greater than that of heifers ($P < 0.001$; Table 5). Birth weight of calves born to L-L-L-H heifers were less than calves born to M-M-M-M and L-H-M-M heifers ($P < 0.05$; Table 5). Calf BW increased linearly for the first 27 d (Figure

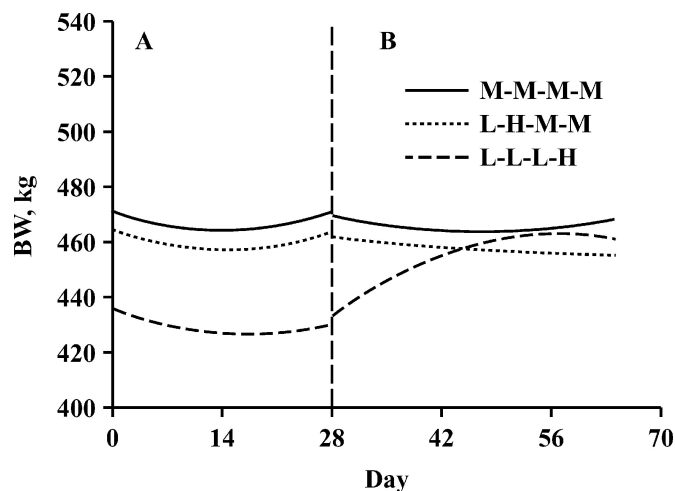


Figure 2. A) Body weight from parturition through 27 d of lactation of heifers fed moderately [—, M-M-M-M; $f(t) = 0.03585(\pm 0.02761)t^2 - 0.9949(\pm 0.8031)t + 471(\pm 4)$ and ..., L-H-M-M; $f(t) = 0.03363(\pm 0.0296)t^2 - 0.03363(\pm 0.8578)t + 464(\pm 0.5)$] or low [---, L-L-L-H; $f(t) = 0.0294(\pm 0.0267)t^2 - 1.0138(\pm 0.7735)t + 435(\pm 0.4)$]. B) Body weight from 28 d through 63 d of lactation of heifers fed moderately [—, M-M-M-M; $f(t) = 0.0158(\pm 0.0169)t^2 - 1.4906(\pm 1.5914)t + 499(\pm 34)$ and ..., L-H-M-M; $f(t) = 0.0022(\pm 0.0177)t^2 - 0.3694(\pm 1.6671)t + 470(\pm 0.36)$] or high [---, L-L-L-H; $f(t) = -0.0357(\pm 0.0169)t^2 + 4.0673(\pm 1.5886)t + 347(\pm 0.34)$].

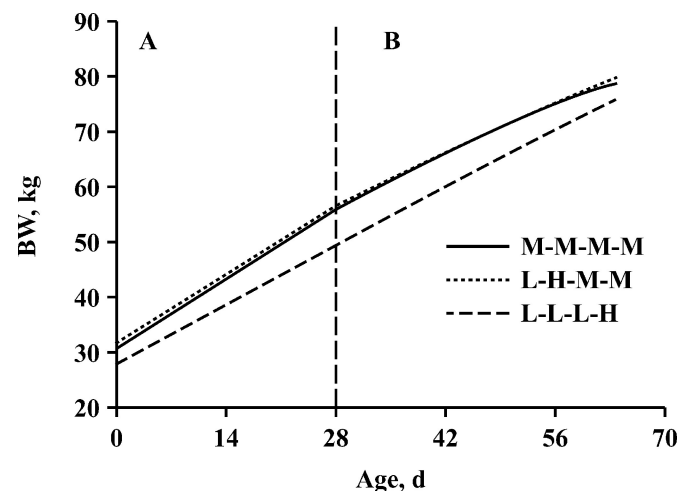


Figure 3. A) Body weight of calves from birth through 27 d of age born to heifers fed moderately [—, M-M-M-M; $f(t) = 0.907(\pm 0.034)t + 30.98(\pm 0.59)$ and ..., L-H-M-M; $f(t) = 0.905(\pm 0.039)t + 31.9(\pm 0.68)$] or low [---, L-L-L-H; $f(t) = 0.771(\pm 0.034)t + 28.1(\pm 0.60)$]. B) Body weight of calves from 28 d through 63 d of age born to heifers fed moderately [—, M-M-M-M; $f(t) = -0.0040(\pm 0.0041)t^2 - 1.0148(\pm 0.3866)t + 31.0(\pm 8.34)$ and ..., L-H-M-M; $f(t) = -0.0016(\pm 0.0043)t^2 - 0.8029(\pm 0.4060)t + 35.7(\pm 8.8)$] or high [---, L-L-L-H; $f(t) = -0.0011(\pm 0.0045)t^2 + 0.8373(\pm 0.4254)t + 27.2(\pm 9.2)$].

Table 5. Body weights (kg) of calves from first-calf heifers (values are least squares means \pm SE)

Treatment ^a	n	Birth	n	28 d of age	n	~66 d of age	n	Weaning	n	365 d
M-M-M-M	44	31.6 \pm 0.6 ^b	40	57.1 \pm 1.1 ^b	40	81.5 \pm 1.7	38	137.5 \pm 3.0	38	342.4 \pm 5.3
L-H-M-M	40	31.8 \pm 0.6 ^b	40	57.5 \pm 1.1 ^b	40	81.1 \pm 1.6	38	134.4 \pm 2.9	36	344.8 \pm 5.2
L-L-L-H	43	28.2 \pm 0.6 ^c	42	49.8 \pm 1.1 ^c	42	77.6 \pm 1.6	39	130.1 \pm 2.9	39	330.5 \pm 5.1
Pooled						79.9 \pm 1.0		133.6 \pm 1.7		337.7 \pm 3.7
Male	64	31.8 \pm 0.5	59	56.3 \pm 0.9		82.4 \pm 1.4	56	139.5 \pm 2.4	55	362.0 \pm 4.3
Female	63	29.3 \pm 0.5	63	53.2 \pm 0.9		77.8 \pm 1.3	59	128.6 \pm 2.3	58	316.4 \pm 4.2
Treatment (T)		<0.001		<0.001		0.18		0.19		0.11
Sex (S)		<0.001		0.01		0.02		0.002		<0.001
Year (Y)		0.98		0.16		0.002		0.72		0.39
T \times S		0.26		0.16		0.23		0.29		0.22
T \times Y		0.18		0.17		0.70		0.37		0.76
S \times Y		0.63		0.63		0.45		0.70		0.25

^aM-M-M-M dams were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M dams were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H dams were fed to have low BW gains from 94 d of gestation through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c}Within a column means without a common superscript letter differ, $P < 0.05$.

3). Daily gain of M-M-M-M (0.91 ± 0.03 kg/d) and L-H-M-M (0.91 ± 0.04 kg/d) calves did not differ from one another ($P > 0.05$); however, ADG was greater for the M-M-M-M and L-H-M-M calves than the L-L-L-H calves (0.77 ± 0.03 kg/d; $P < 0.05$). Consistent with the rates of gain, 28-d BW for M-M-M-M and L-H-M-M calves did not differ ($P > 0.05$), and both had greater 28-d BW than the L-L-L-H calves ($P < 0.05$; Table 5). Calf BW did not differ between treatments when cows were placed into breeding (66.1 ± 0.2 d of age; $P = 0.18$), and treatments did not differ in their 365-d BW (Table 5; $P = 0.11$). Male calves remained heavier than female calves from birth to 365-d BW (Table 5).

Production Inputs and Outputs. Feed intakes during treatment periods followed the pattern that feed was offered (Table 6). The L-L-L-H heifers ate less feed than did M-M-M-M and L-H-M-M heifers during the treatment periods (Table 6). Fewer M-M-M-M heifers were retained for breeding than L-H-M-M heifers, and retention of L-L-L-H heifers was intermediate (Table 7). The lower retention of M-M-M-M heifers was primarily due to losses associated with abortion ($n = 2$) and parturition

($n = 4$). One L-H-M-M heifer aborted, and two L-L-L-H heifers were removed, one each for aborting and calf death at birth. Treatments did not differ in the percentage of calves weaned nor in the weight of calf weaned (Table 7). The percentage of first-calf heifers bred that were retained (had a nursing calf at the start of breeding) did not differ between treatments (Table 7). The time between a heifer being placed with a bull and parturition of her second calf did not differ ($P = 0.23$) between M-M-M-M (299 ± 2 d), L-H-M-M (302 ± 2 d), and L-L-L-H (297 ± 2 d) heifers.

Cows (Second Parity)

Cow Body Weight. Body weight increased quadratically for all treatments from 112 through 203 d after initial bull exposure (Figure 4), and treatments differed in both the quadratic (treatment \times time²; $P = 0.001$) and linear (treatment \times time; $P < 0.001$) terms. Rate of gain increased linearly as a function of days after initial bull exposure for M-M-M-M ($f(t) = 0.03258t - 0.002$), L-H-M-M ($f(t) = 0.00919t - 1.200$), and L-L-L-H ($f(t) =$

Table 6. Dry matter intake from the second trimester to breeding of first-calf heifers (values are least squares means \pm SE)

Treatment ^a	Second trimester (94 to 186 d)		Third trimester (187 d to parturition)			Lactation					Total DMI, kg	
	n	DMI, kg	n	Days	DMI, kg	Parturition to 27 d		28 d breeding				
						n	DMI, kg	n	Days	DMI, kg		
M-M-M-M	44	674 ± 4 ^b	44	93.2 ± 0.8	819 ± 10 ^b	40	259 ± 3 ^b	40	38.2 ± 0.3	384 ± 7 ^b	40	2,130 ± 18 ^b
L-H-M-M	40	521 ± 4 ^c	40	95.6 ± 0.9	938 ± 10 ^c	40	264 ± 3 ^b	40	38.0 ± 0.3	377 ± 7 ^b	40	2,100 ± 17 ^b
L-L-L-H	43	522 ± 4 ^c	43	94.3 ± 0.8	679 ± 10 ^d	42	219 ± 3 ^c	42	38.2 ± 0.3	530 ± 7 ^c	42	1,950 ± 17 ^c
Pooled												
Treatment (T)		<0.001		0.14	<0.001		<0.001		0.84	<0.001		<0.001
Year (Y)		<0.001		0.05	0.19		<0.001		0.64	0.22		0.04
T × Y		0.44		0.22	0.07		0.37		0.82	<0.001		0.94

^aM-M-M-M heifers were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M heifers were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H heifers were fed to have low BW gains from 94 d of gestation through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c,d}Within a column means without a common superscript letter differ, $P < 0.05$.

Table 7. Retention, weaning percent, and pregnancy percent of first-calf heifers (values are least squares means \pm SE)

Treatment ^a	n	Heifers retained, %	n	Calves weaned, %	n	Weaned calf, kg	n	Heifers pregnant, %
M-M-M-M	46	85 \pm 5 ^b	46	83 \pm 6	46	111.9 \pm 7.0	39	90 \pm 5
L-H-M-M	41	98 \pm 2 ^c	41	93 \pm 4	41	125.1 \pm 7.3	39	95 \pm 4
L-L-L-H	44	95 \pm 3 ^{bc}	44	89 \pm 4	44	115.9 \pm 7.1	42	95 \pm 3
Pooled				88 \pm 3		117.3 \pm 4.1		93 \pm 2
Treatment (T)		0.02		0.11		0.42		0.29
Year (Y)		0.04		0.12		0.36		0.29
T \times Y		0.31		0.15		0.28		0.31

^aM-M-M-M heifers were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M heifers were fed to have low BW gains from 94 through 187 d of gestation, rapid weight gain 188 d of gestation to parturition, and moderate BW gain during lactation. L-L-L-H heifers were fed to have low BW gains from 94 d of gestation through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c}Within a column means without a common superscript letter differ, $P < 0.05$.

0.00939t – 1.280) cows. Lower rates of gain resulted in lighter BW for L-H-M-M and L-L-L-H cows compared with M-M-M-M cows at 204 d after initial bull exposure (Table 8). At 204 d, BCS was higher for M-M-M-M cows compared with L-H-M-M and L-L-L-H cows (Table 9).

From 204 d after initial bull exposure to parturition, BW changes over time differed quadratically among treatments (treatment \times time²; $P = 0.005$). The M-M-M-M and L-L-L-H cows continued to increase in BW at an increasing rate; however, BW of L-H-M-M cows increased at a decreasing rate (Figure 4). At parturi-

tion, M-M-M-M and L-H-M-M cows did not differ in BW (Table 8) or BCS (Table 9) and both treatments weighed more and had higher BCS than did L-L-L-H cows.

Within the first 28 d after parturition, BW decreased in all treatments and then increased in a quadratic (time²; $P < 0.001$) manner (Figure 5). Treatments did not differ in either the quadratic (treatment \times time²; $P = 0.15$) or linear terms (treatment \times time; $P = 0.09$). Twenty-eight days after parturition, M-M-M-M and L-H-M-M cows did not differ in BW ($P > 0.26$), but both were heavier than L-L-L-H cows (Table 8; $P < 0.06$). From 28 d of lactation until breeding (63.7 \pm 0.2 of lactation) BW changed quadratically (time²; $P = 0.03$) over time and treatments differed in the linear component (treatment \times time; $P = 0.03$). The M-M-M-M cows decreased in BW, and L-H-M-M cows tended to maintain BW, but BW increased at a decreasing rate for the L-L-L-H cows (Figure 5). At 63.7 \pm 0.4 d of lactation, L-L-L-H cows were heavier than L-H-M-M cows ($P > 0.04$) and M-M-M-M cows were intermediate (Table 8). Body condition score did not differ between treatments at 63.7 \pm 0.4 d of lactation ($P = 0.20$; Table 9).

Calf Body Weights. There was a tendency ($P = 0.07$; Table 10) for a treatment difference in birth weight, with calves born to M-M-M-M cows being the heaviest and calves born to L-L-L-H cows being the lightest. Calf BW increased linearly for the first 27 d of age and treatments differed (treatment \times time; $P = 0.03$) in their rates of gain ($P < 0.013$). Daily gain for M-M-M-M calves was 0.82 \pm 0.04 kg/d, for L-H-M-M calves was 0.72 \pm 0.05 kg/d, and for L-L-L-H calves was 0.72 \pm 0.04 kg/d (Figure 6). Twenty-eight-day weights differed between treatments and followed the same pattern as birth weights. From 28 to 63.7 \pm 0.4 d of age, BW increased at an increasing rate (time²; $P = 0.04$), and treatments did not differ in the quadratic (treatment \times time²; $P = 0.46$) or linear terms (treatment \times time; $P = 0.87$). At 63.7 \pm 0.4 d of age, calf BW did not differ between treatments, nor were there treatment differences at weaning and at 365 d of age (Table 10).

Production Inputs and Outputs. Feed intakes during treatment periods followed the pattern that feed was

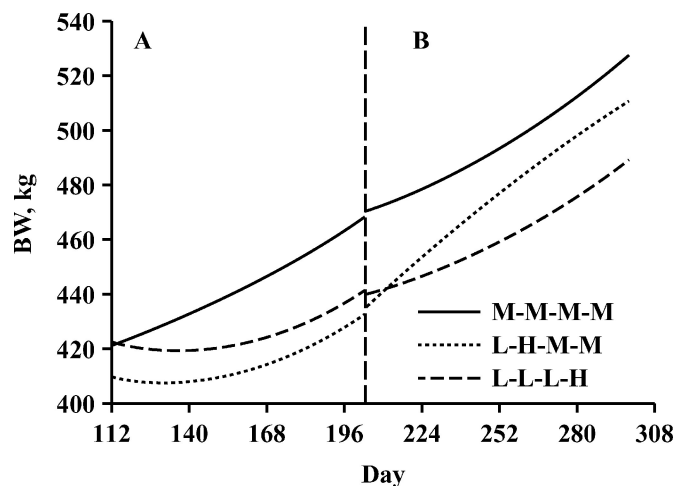


Figure 4. A) Body weight from 112 through 203 d after the start of breeding for cows fed moderately [—, M-M-M-M; $f(t) = 0.0016(\pm 0.0029)t^2 - 0.0002(\pm 0.9142)t + 401(\pm 70)$] or low [..., L-H-M-M; $f(t) = 0.0046(\pm 0.0027)t^2 - 1.19998631t + 486(\pm 66)$ and ---, L-L-L-H; $f(t) = 0.0047(\pm 0.0028)t^2 - 1.2802(\pm 0.8910)t + 507(\pm 68)$]. B) Body weight from 204 d of gestation to parturition of cows fed moderately [—, M-M-M-M; $f(t) = 0.0027(\pm 0.00025)t^2 - 0.7567(\pm 1.2599)t + 513(\pm 155)$], high [..., L-H-M-M; $f(t) = -0.0015(\pm 0.0026)t^2 - 1.5644(\pm 1.3022)t + 180(\pm 161)$], or low [---, L-L-L-H; $f(t) = 0.0026(\pm 0.0028)t^2 - 0.7853(\pm 1.3755)t + 493(\pm 170)$].

Table 8. Body weights (kg) of second-calf cows (values are least squares means \pm SE)

Treatment ^a	After mating					Lactation				
	n	112 d	n	203 d	n	Parturition	n	28 d	n	63.7 ± 0.4 d
M-M-M-M	32	422 ± 6	32	467 ± 7 ^b	32	472 ± 7 ^b	31	462 ± 8 ^b	31	454 ± 8 ^b
L-H-M-M	33	412 ± 6	33	432 ± 6 ^c	33	468 ± 7 ^b	31	449 ± 8 ^b	31	448 ± 8 ^b
L-L-L-H	36	425 ± 6	36	443 ± 6 ^c	36	441 ± 7 ^c	35	429 ± 7 ^c	35	478 ± 8 ^c
Pooled		412 ± 3								
Treatment (T)		0.30		<0.001		0.003		0.01		0.02
Year (Y)		0.87		0.21		0.05		0.02		0.07
T × Y		0.38		0.12		0.02		0.12		0.88

^aM-M-M-M cows were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M cows were fed to have low BW gains from 112 through 203 d after the start of breeding, rapid weight gain 204 d after the start of breeding to parturition, and moderate BW gain during lactation. L-L-L-H cows were fed to have low BW gains from 112 d after the start of breeding through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c}Within a column means without a common superscript letter differ, $P < 0.05$.

offered (Table 11). The L-L-L-H cows ate less feed than did M-M-M-M and L-H-M-M cows during the treatment periods (Table 11). Treatments did not differ in the number of cows retained ($P = 0.77$), calves weaned ($P = 0.77$), and the weight of weaned calf ($P = 0.63$; Table 12). Treatments did not differ in the percentage of cows that had ovulated before 63.7 ± 0.4 d postpartum ($P = 0.21$; Table 12).

Discussion

Heifers (First Parity)

By design, DMI of the M-M-M-M and L-H-M-M heifers did not differ; however, during the second trimester, L-H-M-M heifers were fed 153 kg less DM. This decrease in DMI was offset by an increase in DM (approximately 95 kg) in the third trimester. The efficiency of gain during the third trimester was greater for the L-H-M-M heifers (0.068 kg of BW/kg of DMI) compared with the M-M-M-M heifers (0.052 kg BW/kg DMI). Ferrell et al. (1976) reported that weight gain of the conceptus of heifers fed either 150 or 215 kcal of ME/kg^{0.75} BW did not differ. During the second trimester, L-H-

M-M heifers consumed approximately 180 kcal of ME/kg^{0.75} BW and M-M-M-M heifers consumed approximately 205 kcal of ME/kg^{0.75} BW. Because weight gain of the conceptus is relatively low during the first two trimesters, we would speculate that fetal growth was not limited in the second trimester for the L-H-M-M cows and increases in BW were due to the weight gain of maternal tissues. Although it is not possible in this study to separate weight gain resulting from fetal growth from that of maternal weight gain, a possible cause for the increase in efficiency in weight gain may be due to compensatory gain in the maternal tissues.

The L-L-L-H heifers consumed less DM than heifers of the other two treatments. Body weights of L-L-L-H and M-M-M-M heifers did not differ from each other at the beginning of the study, nor did they differ at breeding; however, through most of the study, L-L-L-H heifers had lower BW than did the M-M-M-M heifers. Maintenance requirements for the L-L-L-H heifers may have been lower over the course of the study because of their lighter BW. The ratio of cumulative feed to cumulative BW resulted in ratios of 0.0181 for M-M-M-M heifers, 0.0182 for L-H-M-M heifers, and 0.0174 for L-L-L-H heifers. These ratios suggest other factors besides lower

Table 9. Body condition score of second-calf cows (values are least squares means \pm SE)^a

Treatment ^b	n	203 d	n	Parturition	n	Breeding
M-M-M-M	32	4.9 \pm 0.1 ^c	31	4.6 \pm 0.1 ^c	31	4.6 \pm 0.1
L-H-M-M	33	4.1 \pm 0.1 ^d	32	4.4 \pm 0.1 ^c	31	4.3 \pm 0.1
L-L-L-H	36	4.3 \pm 0.1 ^d	35	3.8 \pm 0.1 ^d	35	4.6 \pm 0.1
Pooled						4.5 \pm 0.1
Treatment (T)		<0.001		<0.001		0.20
Year (Y)		<0.001		0.47		0.36
T \times Y		0.23		0.49		0.58

^aBody condition score on a scale of 1 (thin) to 9 (fat).

^bM-M-M-M cows were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M cows were fed to have low BW gains from 112 through 203 d after the start of breeding, rapid weight gain 204 d after the start of breeding to parturition, and moderate BW gain during lactation. L-L-L-H cows were fed to have low BW gains from 112 d after the start of breeding through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{c,d}Within a column means without a common superscript letter differ, $P < 0.05$.

Table 10. Body weights (kg) of calves from second-calf cows (values are least squares means \pm SE)

Treatment ^a	n	Birth	n	28 d of age	n	63.7 \pm 0.4	n	Weaning	n	365 d
M-M-M-M	32	37.0 \pm 0.8	31	59.2 \pm 1.4 ^b	31	78.0 \pm 2.0	31	185 \pm 5	31	356 \pm 8
L-H-M-M	33	35.9 \pm 0.8	31	56.1 \pm 1.3 ^{bc}	31	77.1 \pm 2.0	31	175 \pm 5	31	348 \pm 8
L-L-L-H	36	34.2 \pm 0.8	35	54.1 \pm 1.3 ^c	35	79.1 \pm 1.9	35	183 \pm 5	34	349 \pm 7
Pooled		36.0 \pm 0.5				78.6 \pm 1.3		179 \pm 3		350 \pm 6
Male	50	36.4 \pm 0.7	47	56.3 \pm 1.1	47	78.8 \pm 1.7	47	184 \pm 4	47	394 \pm 6
Female	51	35.1 \pm 0.7	50	56.7 \pm 1.0	50	77.3 \pm 1.5	50	178 \pm 4	49	308 \pm 6
Treatment (T)		0.07		0.02		0.76		0.41		0.74
Sex (S)		0.19		0.78		0.50		0.28		<0.001
Year (Y)		0.001		<0.001		<0.001		0.06		0.29
T \times S		0.99		0.93		0.48		0.22		0.83
T \times Y		0.63		0.69		0.62		0.40		0.75
S \times Y		0.03		0.42		0.55		0.44		0.64

^aM-M-M-M dams were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M dams were fed to have low BW gains from 112 through 203 d after the start of breeding, rapid weight gain 204 d after the start of breeding to parturition, and moderate BW gain during lactation. L-L-L-H dams were fed to have low BW gains from 112 d after the start of breeding through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c}Within a column means without a common superscript letter differ, $P < 0.05$.

BW contributed to the lower DMI. Another potential source may have been a decrease in milk production during the first 28 d of lactation, which is indicated by the reduced rates of gain of their calves from birth to 28 d of age.

Nutrient restriction during pregnancy has been shown to reduce birth weights of calves. Bellows and

Short (1978) reported heifers that had a BCS of approximately 2.5 at parturition had lighter-weight calves at birth than heifers with BCS of approximately 5.5. Others have reported no difference in birth weight of calves from heifers that ranged from 4.0 through 6.1 at parturition (Whittier et al., 1988; Wiley et al., 1991; DeRouen et al., 1994). Our study differed from these studies in that we observed a decrease in birth weight of calves from L-L-L-H heifers even though heifer BCS at partu-

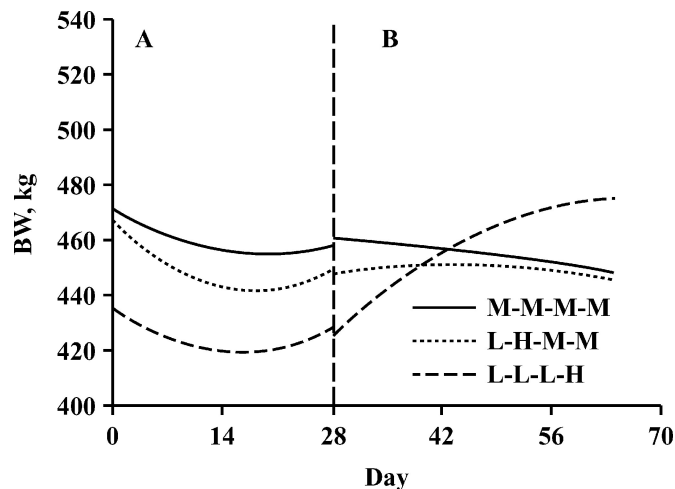


Figure 5. A) Body weight from parturition through 27 d of lactation of cows fed moderately [—, M-M-M-M; $f(t) = 0.0399(\pm 0.0365)t^2 - 1.6030(\pm 1.0531)t + 471(\pm 6)$ and . . . , L-H-M-M; $f(t) = 0.07503(\pm 0.0399)t^2 - 2.73060(\pm 1.1534)t + 466(\pm 6)$] or low [---, L-L-L-H; $f(t) = 0.0591(\pm 0.0434)t^2 - 1.9243(\pm 1.2582)t + 436(\pm 0.7)$]. B) Body weight from 28 through 64 d of lactation of cows fed moderately [—, M-M-M-M; $f(t) = -0.0039(\pm 0.0248)t^2 - 0.0295(\pm 2.3365)t + 463(\pm 51)$ and . . . , L-H-M-M; $f(t) = -0.0140(\pm 0.0255)t^2 + 1.2244(\pm 2.3817)t + 424(\pm 51)$] or high [---, L-L-L-H; $f(t) = -0.0362(\pm 0.0252)t^2 + 4.7158(\pm 2.3673)t + 321(\pm 51)$].

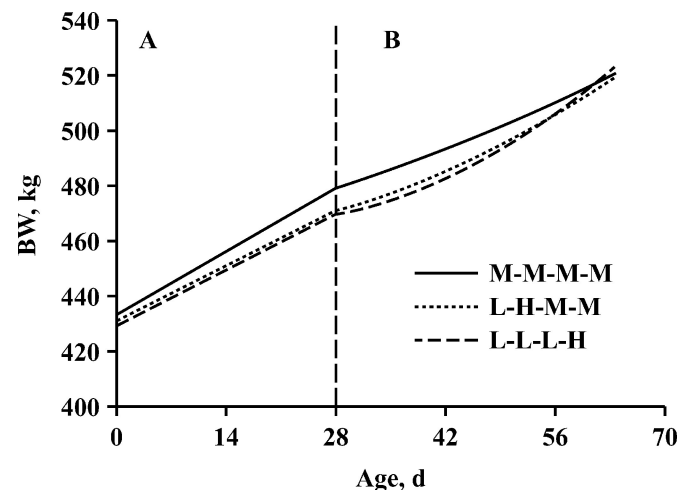


Figure 6. A) Body weight of calves from birth through 27 d of age born to cows fed moderately [—, M-M-M-M; $f(t) = 0.823(\pm 0.041)t + 36.6(\pm 0.7)$ and . . . , L-H-M-M; $f(t) = 0.724(\pm 0.046)t + 35.3(\pm 0.8)$] or low [---, L-L-L-H; $f(t) = 0.724(\pm 0.042)t + 34.6(\pm 0.7)$]. B) Body weight of calves from 28 through 64 d of age born to cows fed moderately [—, M-M-M-M; $f(t) = 0.0027(\pm 0.0046)t^2 + 0.3391(\pm 0.4337)t + 47.9(\pm 9.4)$ and . . . , L-H-M-M; $f(t) = 0.0069(\pm 0.0053)t^2 + 0.0557(\pm 0.4940)t + 48.2(\pm 10.7)$] or high [---, L-L-L-H; $f(t) = 0.0130(\pm 0.0053)t^2 - 0.4374(\pm 0.4954)t + 56.9(\pm 10.7)$].

Table 11. Dry matter intake from the second trimester to breeding of second-calf cows (values are least squares means \pm SE)

Treatment ^a	Second trimester (112 to 203 d)		Third trimester (204 d to parturition)			Lactation					Total DMI, kg	
	n	DMI, kg	n	Days	DMI, kg	Parturition to 27 d		28 d breeding				
						n	DMI, kg	n	Days	DMI, kg		
M-M-M-M	32	547 ± 6 ^b	32	96.1 ± 2.0	755 ± 24 ^b	31	255 ± 3 ^b	31	35.0 ± 0.4	359 ± 10 ^b	31	1,908 ± 25 ^b
L-H-M-M	33	429 ± 6 ^c	33	98.9 ± 2.0	871 ± 23 ^c	31	250 ± 3 ^c	31	35.2 ± 0.4	374 ± 10 ^b	31	1,927 ± 24 ^b
L-L-L-H	36	434 ± 5 ^c	36	94.0 ± 2.0	636 ± 22 ^d	35	223 ± 2 ^d	35	35.6 ± 0.4	514 ± 10 ^c	35	1,797 ± 23 ^c
Pooled												
Treatment (T)		<0.001		0.23	<0.001		<0.001		0.23	<0.001		<0.001
Year (Y)		0.01		0.29	0.12		0.10		<0.001	<0.001		0.55
T × Y		0.08		0.25	0.79		0.01		0.21	<0.001		0.78

^aM-M-M-M cows were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M cows were fed to have low BW gains from 112 through 203 d after the start of breeding, rapid weight gain 204 d after the start of breeding to parturition, and moderate BW gain during lactation. L-L-L-H cows were fed to have low BW gains from 112 d after the start of breeding through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

^{b,c,d}Within a column means without a common superscript letter differ, $P < 0.05$.

rition ranged from 5.1 for L-L-L-H heifers to 5.6 for L-H-M-M and M-M-M-M heifers. Daily BW gain by the L-L-L-H calves was lower the first 28 d compared with the other treatments. Because the only food resource available to the calves was milk, we speculate that the lower rate of gain was due to a lower milk production in L-L-L-H heifers. By 63 d of age, calf BW did not differ between treatments. This lack of difference is a result of a decrease rate of gain in the L-H-M-M and M-M-M-M calves and most likely reflects a decrease in milk production in the L-H-M-M and M-M-M-M heifers. After cows were moved to breeding pastures, nutrient availability was equal across treatments, and BW gains from 63 d of age to weaning were not different. Although calf weights did not differ between treatments from 63 d of age and older, it should be noted that the L-L-L-H calves were consistently the lightest calves.

Two measures of cow productivity are the weight of calf weaned and the proportion of bred heifers that return to breeding with a live calf. In the current study, numerically both the L-H-M-M and L-L-L-H heifers had a higher percentage of heifers return with a calf, suggesting that both of these management systems did

not decrease the number of cows retained compared with the M-M-M-M management system. Treatments did not differ in weight of calf weaned, nor did they differ in the weight weaned per heifer bred. Using cow retention and weight of calf weaned as measures of efficiency of the production system, we would conclude that L-H-M-M and L-L-L-H systems compare favorable with the M-M-M-M system.

Pregnancy rates of heifers bred for a second calf is another measure of the efficacy of a production system. Whittier et al. (1988) concluded pattern of weight gain during pregnancy did not affect conception rates, as long as BW at parturition returned to a target level. In our study, the percentage of heifers that rebred did not differ between the L-H-M-M and M-M-M-M heifers. These findings agree with those of Whittier et al. (1988) and extend their interpretation to suggest that there is flexibility in the pattern of BW gain during the last two trimesters. Furthermore, results of our study suggest that heifers that have undergone a mild feed restriction can compensate for the lower BW by rapid weight gain during the 35 d before breeding without

Table 12. Retention, weaning percent, and presence of a corpus luteum (CL) at breeding for second-calf cows (values are least squares means \pm SE)

Treatment ^a	Cows retained, %		Calves weaned, %		Weaned calf, kg		With a CL, %	
	n		n		n		n	
M-M-M-M	33	94 \pm 4	33	94 \pm 4	33	172 \pm 9	31	81 \pm 7
L-H-M-M	34	91 \pm 5	34	91 \pm 5	34	161 \pm 9	31	71 \pm 8
L-L-L-H	37	95 \pm 4	37	95 \pm 4	37	171 \pm 9	35	89 \pm 5
Pooled		93 \pm 2		93 \pm 2		167 \pm 5		80 \pm 4
Treatment (T)		0.77		0.77		0.63		0.21
Year (Y)		0.28		0.28		0.15		0.49
T \times Y		0.18		0.17		0.62		0.96

^aM-M-M-M cows were fed to have moderate BW gains during pregnancy and lactation. L-H-M-M cows were fed to have low BW gains from 112 through 203 d after the start of breeding, rapid weight gain 204 d after the start of breeding to parturition, and moderate BW gain during lactation. L-L-L-H cows were fed to have low BW gains from 112 d after the start of breeding through 27 d lactation and rapid BW gain from 28 d of lactation until breeding.

decreasing the number of heifers that become pregnant.

Cows (Second Parity)

Dry matter intake for cows followed the same pattern as it did for heifers. The 118-kg reduction in DMI in the second trimester for L-H-M-M cows was offset by an approximately 93-kg increase in the third trimester. Cows on the L-L-L-H treatment consumed less total DM than the other cows. Because the L-L-L-H cows had a lighter BW during the third trimester and early lactation, they most likely had a lower nutrient requirement to maintain BW. This reduction in DMI for maintenance is supported by the ratio of cumulative feed to cumulative BW, where the ratio for M-M-M-M cows was 0.0163 kg of DM/kg BW, and the ratio for L-H-M-M cows was 0.0170 kg of DM/kg BW, and the ratio for L-L-L-H cows 0.0163 kg of DM/kg BW.

Restricting feed to the L-L-L-H cows during pregnancy resulted in lighter weight cows at parturition. Increasing the feed offered to L-L-L-H cows 28 d after parturition resulted in BW gain in the cow and an increased rate of gain by the calf. Because milk was the only food source available to the calf, we speculate that increased weight gain by calves was due to increased milk production. These data suggest cows that have been nutrient restricted and refed partition the additional feed resources into both BW and milk. If milk production increases, it seems that mild nutrient restriction during pregnancy does not decrease the capacity of the cow to produce milk, but rather limits the substrates available to produce milk.

Cows that were in nutritional anestrus as a result of the nutritional treatments would not have a corpus luteum before the start of the breeding period (64 d postpartum). The lack of treatment differences for the percentage of cows that were cycling at the start of breeding suggests that treatments did not negatively affect folliculogenesis or ovulation rate. However, these data do not address other factors that influence pregnancy rates, such as ovum quality, efficiency of implantation, or the proportion of cows that may have commenced ovulation during the breeding season. The absence of treatment differences in cows retained, calf weight weaned, and percentage of cows cycling at the start of breeding suggests that all three management schemes can be used successfully.

Conclusion

Many studies have demonstrated that inadequate or improperly timed nutrition can decrease cow productiv-

ity; however, in mature cows, timing nutrient availability and allowing BW fluctuations are alternative management options for feed resources (Freetly et al., 2000). Because of the additional nutrient required for growth, heifers and primiparous cows are typically more prone to reproductive failure resulting from poor nutrition. Our findings suggest that timing nutrient availability to heifers and primiparous cows can be used to change the time that feed resources are used. Maintaining cows at a lower BW over extended periods of time decreases the feed input into the production system, but additional feed still needs to be provided at critical times in the production cycle. Trends for numerically lighter weight calves from first-calf heifers maintained at low BW over extended periods suggest further evaluation of this treatment should be conducted before it is used in a production system.

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